TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 33

THE EFFECT OF THE NATURE OF SURFACES ON RESISTANCE, AS TESTED ON STRUTS.

By

Dr. Ing. C. Wieselsberger.

Translated from
"Zeitschrift für Flugtechnik und Motorluftschiffahrt,
February 28,1920,
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It has been shown by measurements previously taken of model balloons,** that comparatively slight alterations in surface may have considerable effect upon the resistance of a body. Reference need only be made to the very striking results obtained by those tests as regards the resistance of a model balloon covered with fabric. The raised threads of the fabric having been scorched with flame, the resistance of the balloon more than doubled in value, contrary to any procedure hitherto observed, when the REYNOLDS symbol increased from about 100000 to 250000.

In testing struts, similar observations have been made and are briefly reported as follows.*** The struts in ques-

* Notes communicated by the aerodynamic model testing laboratory at Göttingen.

** Compare C. WIESELSBERGER'S "Similitude Tests of Model Balloons and on the Effect of the Nature of Surfaces," Bul. 20, of the Göttingen Laboratory. Published in the "Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1915, p.125.

*** The first series of measurements was made during the War on behalf of the Deutschen Flugzeugwerke, Leipzic. The strking nature of the results obtained led to further measurements being taken in a second series of tests carried out at the Laboratory.

tion were mostly of great thickness, like those used in constructing giant aircraft. Their shapes and dimensions are given in Fig. 1. The thickness of the largest strut was d = 177 mm. The wind velocity being raised to 45 m/s, characteristic values of E were attained up to about 8000 m/sec mm., that is, the product of the velocity of the air and the thickness of the struts. The length of the struts was 2.5 m. They were measured at that length for resistance, and as the diameter of the airflow was only 2.23 m., the struts projected out of it, at each end, into the still air. To what extent such airflow conditions resemble those corresponding to unlimited length of strut, that is, to uniform airflow, was established by means of special tests which are to be reported later on.

As we are at present chiefly concerned with the variations of resistance brought about by the nature of the surface, the measurement of such resistance will not be subjected to any particular regulation. It need only be mentioned that the method of testing employed evidently produces somewhat higher resistance than when the airflow is perfectly uniform. The direction of the airflow was parallel, in all cases, to the line of symmetry of the profile. In calculating the resistance C_W, only the largest strut surface affected by the airflow - that is, perpendicular to the direction of the wind - was always employed.

The struts were spanned with linen (aviation linen), and then covered with one coat of varnish. The top surface was

not perfectly smooth after this treatment, being slightly rough owing to the threads and raised fibers of the fabric. The results of the measurements of the surface of such nature are shown by the dotted lines of the curves plotted in Figs. 2 to 8, (Pl.B.18) the resistance being given in terms of the characteristic value. It is astonishing to find that the resistance increases again, after first diminishing with the decrease of characteristic value, to more than double the quantity of the lowest resistance in many cases, as, for instance, in struts 3 and 7. The decrease that takes place at the outlet corresponds to the passage through the region of critical velocity, as has been previously observed in the case of spheres and bodies of other shapes. The fact of there being little or no rising tendency on the part of struts 4 and 5 may be due to the accidental presence of less roughness in the fabric.

The surface was then altered by the removal of any roughness on it by means of filing with sandpaper. The measurements of surfaces thus treated gave values represented by the extended lines. The increase of resistance with increasing characteristic value, more or less marked in the first series of measurements, was no longer observable. Resistance always decreases with the increase of characteristic value, excepting in the case of strut 7, which shows a slight tendency to rise again.

The reasons for this phenomenon have not yet been fully explained. A theoretic treatment of the preceding matter

has not yet been possible. The variation of resistance depends, as is well known, upon the change of position of the point of separation of the air filaments, which is, again, in close relation to the turbulency conditions of the separating air layer. When there is a turbulent separating air layer, bodies of the shape in question usually offer less resistance than in the case of a lamina surface of separation. The factors that come into play in the renewed resistance should therefore be thoroughly investigated.

It may be as well to mention the low absolute value of that resistance, which decreases, under the most favorable circumstances, to $C_w = 5$ in the case of strut 3.

Table 1.

strut no. 1. With slightly rough surface. $d = 54$ mm.

Dynamic Pressure q kg/m^2	Resistance W g	Coefficient of Resistance C_w	Velocity v m/s	Characteristic value: E mm . m/s
6.3	118	15.5	10.1	546
13.8	147	8.85	14.9	805
25.0	268	8.90	20.0	1080
38.7	397	8.55	24.9	1345
56.0	554	8.20	30.0	1620
76.0	802	8.79	34.9	1885
100.0	1096	9.12	40.0	2160
125.5	1335	8.83	44.9	2438
154.0	1693	9.16	49.6	2676

2. With smoothed surface.

6.2	149	19.9	10.0	539
14.0	169	10.0	15.0	809
24.9	269	8.96	19.9	1077
39.1	402	8.54	25.0	1350
56.5	563	8.26	30.0	1620
76.8	749	8.08	35.0	1891
100.0	970	8.05	40.0	2160

$q = \frac{1}{2} \times \frac{1}{8} v^2$

$= \frac{1}{16} v^2$

$v = 4\sqrt{q}$

$.305$ m $= 1$ ft

$\frac{E}{.305 \quad 305}$

$\frac{E}{93}$

Table 2.

STRUT No. 2 Thickness d = 75 mm.

1. With slightly rough surface.

Dynamic Pressure q kg/m^2	Resistance W g	Coefficient of Resistance C_w	Velocity v m/s	Characteristic value: E mm. m/s
6.3	198	18.7	10.1	758
14.2	196	8.25	15.0	1125
25.0	297	7.10	20.0	1500
38.7	481	7.41	24.9	1868
56.1	722	7.71	30.0	2250
76.0	997	7.82	34.9	2620
100.0	1336	7.97	40.0	3000
125.5	1705	8.12	44.9	3370
154.0	2153	8.35	49.6	3720

2. With smoothed surface.

6.4	221	20.7	10.1	758
6.3	159	15.1	10.0	1753
14.0	194	8.25	15.0	1125
25.1	304	7.23	20.0	1500
39.0	441	6.74	25.0	1873
56.5	609	6.42	30.1	2255
76.8	801	6.23	35.0	2628
100.0	1036	6.19	40.0	3000

Table 3.

STRUT No. 3 Thickness d = 85 mm.

1. With slightly rough surface.

Dynamic Pressure q kg/m²	Resistance W g	Coefficient of Resistance C_W	Velocity v m/s	Characteristic value E mm . m/s
6.3	193	16.0	10.1	758
14.2	206	7.64	15.0	1275
25.0	352	7.40	20.0	1700
38.7	639	8.70	24.9	2118
56.1	1163	10.9	30.0	2550
76.1	1775	12.2	34.0	2965
100.0	2506	13.2	40.0	3400
127.5	3505	14.5	45.1	3830
155.2	4333	14.7	49.9	4240

2. With smoothed surface.

6.7	210	16.6	10.3	880
14.4	211	7.74	15.2	1290
25.6	305	6.30	20.5	1742
39.7	410	5.46	25.4	2160
56.6	574	5.36	30.2	2565
77.5	652	4.44	35.2	2990
100.5	910	4.79	40.1	3410
127.2	1060	4.40	45.1	3830

Table 4.

STRUT No. 4 Thickness d = 94 mm.

1. With slightly rough surface.

Dynamic Pressure q kg/m^2	Resistance W g	Coefficient of Resistance C_W	Velocity v m/s	Characteristic value E mm . m/s
6.2	301	23.3	9.92	933
14.0	234	7.98	15.0	1405
24.8	278	7.45	19.9	1870
38.9	538	6.61	25.0	2345
56.6	729	6.13	30.0	2820
76.0	1005	6.28	34.8	3270
99.0	1305	6.24	39.8	3740
125.1	1642	6.27	44.7	4210
154.1	2064	6.36	49.6	4665

2. With smoothed surface.

Dynamic Pressure q kg/m^2	Resistance W g	Coefficient of Resistance C_W	Velocity v m/s	Characteristic value E mm . m/s
6.2	329	25.2	10.0	938
14.0	248	8.43	15.0	1405
24.9	378	7.22	20.0	1875
39.2	545	6.62	25.0	2345
56.5	752	6.34	30.1	2827
76.8	984	6.11	35.0	3290
100.0	1267	6.03	40.0	3760

Table 5.

STRUT No. 5. Thickness d = 130 mm.

1. With slightly rough surface.

Dynamic Pressure q kg/m²	Resistance W g	Coefficient of Resistance C_w	Velocity v m/s	Characteristic value E mm . m/s
6.2	159.6	8.90	9.96	1294
14.0	305.5	7.50	15.0	1950
24.8	507.0	7.04	19.9	2587
38.8	792.0	7.04	25.4	3290
56.2	1169.0	7.15	30.0	3900
76.2	1655.0	7.48	35.1	4560
99.6	2286.0	7.91	40.0	5200
101.5	2576.0	8.45	40.3	5230
155.0	4118.0	9.15	49.8	6475

2. With smoothed surface.

6.5	---	8.55	10.2	1323
14.3	306	7.37	15.1	1964
25.2	500	6.84	20.1	2608
39.0	749	6.61	25.0	3247
56.5	1064	6.48	30.0	3900
76.8	1411	6.32	35.0	4550
100.0	1842	6.34	40.0	5200

Table 6.

STRUT No. 6 Thickness d = 154 mm.

1. With slightly rough surface.

Dynamic Pressure q kg/m^2	Resistance W g	Coefficient of Resistance C_W	Velocity v m/s	Characteristic value E mm . m/s
6.3	194	8.9	10.1	1555
14.8	424	8.4	15.4	2372
25.0	875	10.2	20.0	3080
38.7	1572	11.9	24.9	3834
56.1	2428	12.6	30.0	4620
76.0	3645	13.9	34.9	5375
100.0	4606	13.4	40.0	6160
125.5	6135	13.8	45.6	7020
154.0	7523	14.2	49.6	7640

2. With smoothed surface.

6.3	201	9.26	10.3	1586
14.2	397	8.13	15.1	2320
25.1	656	7.61	20.0	3080
39.2	969	7.19	25.0	3850
56.4	1363	7.02	30.0	4620
76.5	1819	6.90	35.0	5385
100.0	2367	6.88	40.0	6160

Table 7.

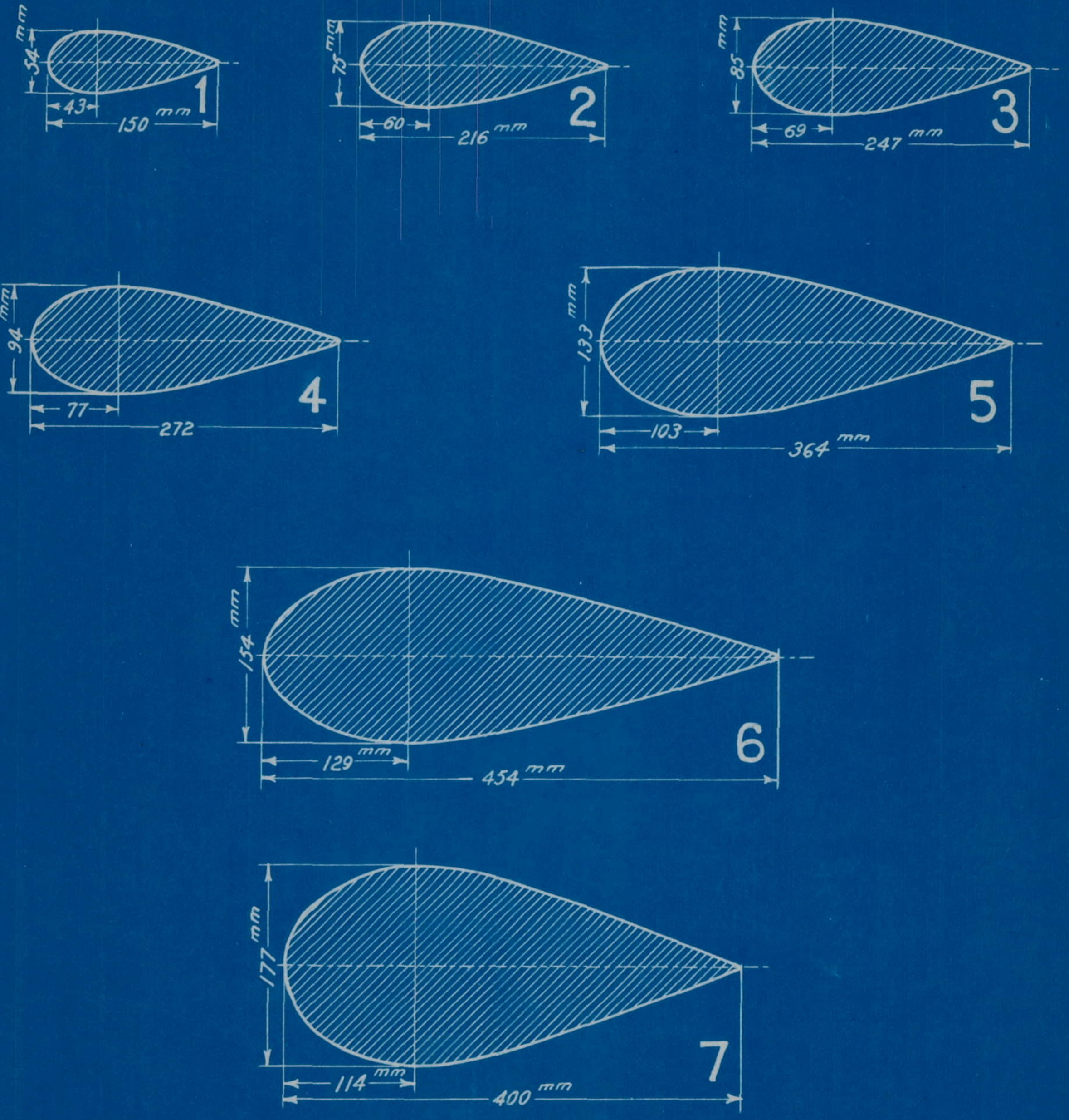
STRUT No. 7 Thickness d = 177 mm.

1. With slightly rough surface.

Dynamic Pressure q kg/m²	Resistance W g	Coefficient of Resistance c_w	Velocity v m/s	Characteristic value E mm. m/s
6.2	247.2	10.1	9.92	1760
13.9	494.5	9.00	14.9	2638
24.6	1104.0	11.4	19.8	3510
38.4	2324.0	15.3	24.8	4390
56.3	4058.0	18.2	30.0	5310
76.0	5935.0	19.5	34.8	6160
99.0	7961.6	20.4	39.8	7050
125.0	10835.0	21.8	44.8	7930
154.1	14003.0	23.0	49.6	8770

2. With smoothed surface.

6.3	246	9.87	10.0	1780
14.3	456	8.06	15.1	2680
25.2	751	7.55	20.2	3575
39.2	1114	7.19	25.0	4435
56.7	1629	7.27	30.1	5330
76.7	2120	7.00	35.0	6195
100.3	2965	7.49	40.0	7090
128.2	3870	7.66	45.3	8010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43
150 mm
1
75 mm
60
216 mm
2
85 mm
69
247 mm
3
94 mm
77
272
4
133 mm
103
364 mm
5
154 mm
129 mm
454 mm
6
177 mm
114 mm
400 mm
7

Fig. 1.

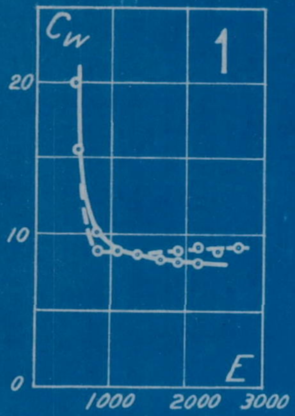


Fig. 2.

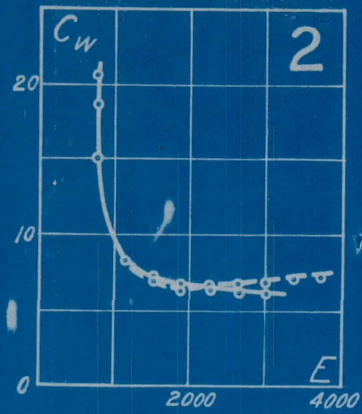
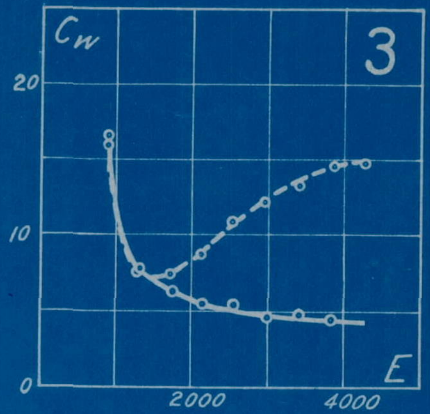


Fig. 3.



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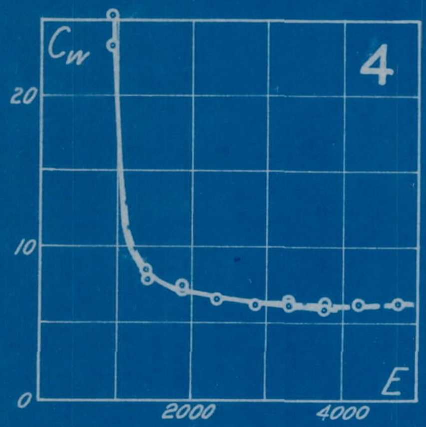

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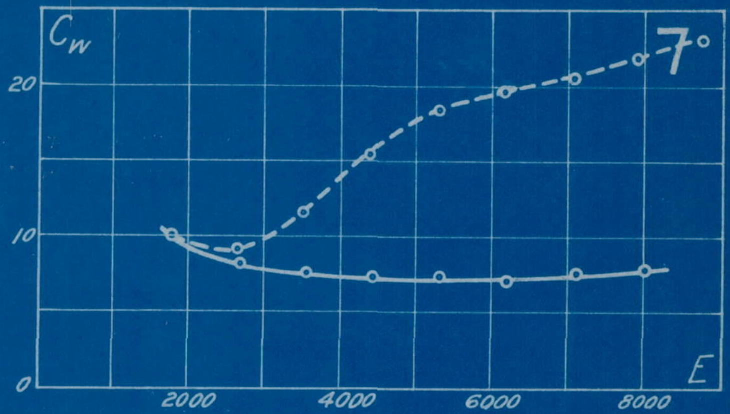

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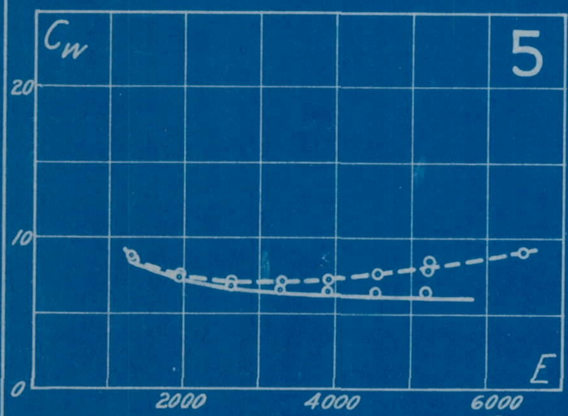

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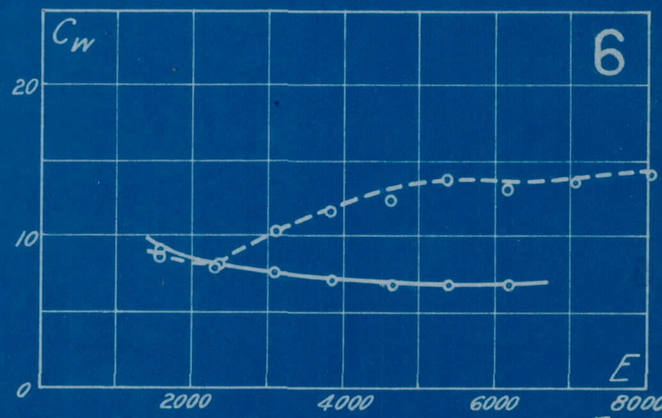

Fig. 7.

Figs. 2,3,4,5,6 & 7.